Blake. (C. J.)

THE USE OF THE MEMBRANA TYMPANI

AS A

PHONAUTOGRAPH AND LOGOGRAPH.

By CLARENCE J. BLAKE, M.D.,

BOSTON.

Reprinted from the ARCHIVES OF OPHTHALMOLOGY AND OTOLOGY, *Vol. VII., Nos. II., III., and IV.*

NEW YORK:
WILLIAM WOOD & COMPANY, 27 GREAT JONES STREET.
1879.

THE USE OF THE MEMBRANA TYMPANI

AS A

PHONAUTOGRAPH AND LOGOGRAPH.

By CLARENCE J. BLAKE, M.D.,

BOSTON.

Reprinted from the ARCHIVES OF OPHTHALMOLOGY AND OTOLOGY, *Vol. VII., Nos. II., III., and IV.*

NEW YORK:
WILLIAM WOOD & COMPANY, 27 GREAT JONES STREET.
1879.

THE USE OF THE MEMBRANA TYMPANI AS A PHONAUTOGRAPH AND LOGOGRAPH.

By CLARENCE J. BLAKE, M.D., Boston.

Continued from Archives of Ophthalmology and Otology, Vol. V., No. 1, 1876.

At the time of the publication of the first paper on this subject, which appeared in these Archives in 1876, it was intended to continue the work in a series of communications, which should give the results of further experiments in relation to the system of "Visible Speech," originally devised for the instruction of deaf-mutes by Prof. A. Melville Bell. Various circumstances, among them a participation in the interesting telephonic researches of Prof. A. Graham Bell, prevented the carrying out of this intention. Since the publication of the first paper mentioned, great advances have been made in the graphic study of sonorous vibrations, and especially in the study of the recorded vibrations produced by the human voice. The phonograph of Edison especially has given an impetus to study in this direction which is showing itself in such elaborate observations as those of Prof. Fleeming Jenkin and Mr. Ewing of London,* and of Prof. A. M. Mayer, of the Stevens Institute, Hoboken.†

Since the publication of the first paper in these Archives also, the membrana tympani phonautograph has acquired a certain interest, since it was the use of the instrument there described, in experiments in conjunction with the author, which gave Prof. Bell the clue to the telephone as exhibited in his first membrane telephone at the International Exhibition in 1876.‡

---

* Nature. The Phonograph and Vowel Sounds, July and Aug., 1878.

† Sound. A. M. Mayer, Ph.D. New York, Appleton & Co., 1878.

‡ The Telephone. Prof. A. Graham Bell. Journal of the Society of Arts, Nov. 30th, 1877.

Of the three objections which have been made to the use of the human membrana tympani for the purpose of making phonautograms, one has considerable weight, and another has been disproved by the lapse of time since the first instrument was constructed.

The first is, the difficulty of procuring the proper material.

The second is, that the friction resulting from the use of a smoked surface of glass, mica, or collodion film with so light a stylus as that required in using so delicate a vibrating membrane, materially affects the resultant tracing and gives a less accurate representation of the vibrations of the membrane than can be obtained in other ways. In a paper on the photographic reproduction of sonorous vibrations, Prof. E. W. Blake, Jr., mentions the measurement of some of the tracings made from the membrana tympani on smoked glass, and shows that the number of recorded vibrations falls considerably below the ordinary pitch of the voice, being in some cases as low as eighty per second.*

The third objection is, that the membrana tympani and the ligaments of the ossicles become in time so changed by exposure as to be useless for phonautographic purposes. This objection is answered by the fact that the instrument first described by me is still in use with the same membrana tympani, and the tracings which it now gives bear favorable comparison with those first made.

A review of the history of the phonautograph in its various forms shows that the transcription of the vibrations of the membrana tympani and ossicles was first suggested by Prof. Adam Politzer, who published, in 1864, a series of interesting experiments upon the graphic method of illustrating such vibrations.† The object of these experiments was to study and to illustrate the vibrations of the membrana tympani and

* A Method of Recording Articulate Vibrations by Means of Photography. E. W. Blake, Jr., Hazard Professor of Physics, Brown University. American Journal of Science and Arts, July, 1878.

† Untersuchungen über Schallleitung und Schallfortpflanzung. Prof. Adam Politzer. Archiv für Ohrenheilkunde, Band I., s. 59.

ossicles in the healthy subject, to determine the effect of the contraction of the musculus tensor tympani upon such vibration, and also to determine comparatively the effect of varying atmospheric pressure.

The means employed for the accomplishment of this purpose were suggested by the previous experiments of Savart, and were carried out with the assistance of König, who placed the then new phonautograph of Leon Scott at the service of the investigator.* The application of these means by Prof. Politzer was, however, both original and ingenious, and constitutes the first record of the phonautographic use of the membrana tympani. The preparations used in these experiments were from the human subject and from birds, the latter being chosen for study of vibrations of the membrane of the oval window, on account of the greater comparative excursions of the columella, and because of the difficulty of attaching the stylus to the base of the human stapes without seriously impairing the function of its membrane.

In the same volume of the Archiv für Ohrenheilkunde, Lucae makes use of the method suggested by Politzer, in his experiments upon sound conduction through the bones of the head, a stylus being attached to one of the ossicula, as in Politzer's experiment, and a vibrating tuning-fork being inserted in the external auditory canal.†

Both of these series of experiments conducted upon the graphic method were physiological in character, being undertaken with the view rather of studying the functions of the sound-transmitting portions of the organ of hearing than of using these structures as a substitute for the apparatus of Scott in the study of aerial vibrations produced by movement of various bodies, or by the human voice.

In the first volume of his recent text-book, Prof. Politzer again refers to his previous experiments and to the great adaptability of the membrana tympani to the reception and

* Archiv für Ohrenheilkunde, Band I., s. 61.

† Untersuchungen über die sogenannte "Knochenleitung," etc., August Lucae, Archiv für Ohrenheilkunde, Band I., s. 303.

transmission of a wide range of musical tones, as compared with any artificial membrane having a plane surface.

"If an artificial membrane stretched over a ring is struck, it gives forth a tone which varies according to the degree of tension of the membrane, and which is its individual tone. Such a membrane vibrates most readily in reponse to a tone corresponding to its individual tone; its vibrations are, however, considerable in response to tones which approximate its individual tone, and less and less in response to tones receding in the musical scale from its individual tone. The membrana tympani, however, possesses the peculiar property of transmitting tones of various pitches, not only in succession, but simultaneously and to our perception in an equal degree. It should on no account be classed as an elastic membrane, the membrana tympani is rather, from the anatomical arrangement of its fibres, a stiff and but slightly elastic membrane and this property is of importance, inasmuch as it prevents consequent vibrations which would interfere with the proper perception of the tone."*

That the use of the human membrana tympani, in conducting physical investigations in this direction, as a substitute for an artificial membrane possesses certain advantages is, therefore, self-evident, provided always that the delicacy of the mechanism employed in making the record corresponds as nearly as possible to that of the human instrument. The first series of the accompanying illustrations represents tracings made upon smoked glass by a stylus attached to the malleus and to the incus in the direction of the long axis of the manubrium and of the long process respectively, in reponse to vowel sounds sung into the mouthpiece of the instrument at various pitches, the recording plate moving at a uniform rate. While these curves correspond very fairly in their general characteristics to those made by the phonautograph of Marey, they differ greatly from curves of corresponding tones obtained by the photographic process, as illustrated in the paper by Prof. E. W. Blake already

* Lehrbuch der Ohrenheilkunde. Prof. Adam Politzer, 1878. Schallfortpflanzung durch Trommelfell und Gehörknöchelchen, Band I., s. 67.

cited; indeed the effect of the increased friction resulting from an increase of speed in the movement of the smoked glass plate was plainly shown in these phonautographic experiments by a greater alteration in the resultant curve than would have resulted from an increase of speed in the movement of the plate alone.

The construction of the ingenious instrument of Mr. Barlow, and the account of his experiments in a paper read before the Royal Society,* demonstrating the varying pneumatic pressure accompanying the production of consonant sounds, has opened a new and very interesting field for investigation, and in connection with the general introduction of the telephone, suggested investigations as to the influence which this varying pneumatic pressure might have upon the movement of a metal disc or membrane vibrating in response to the combined vowel sound† in which the human membrana tympani was used as a logograph, the logographic curves produced by the various consonant sounds corresponding very fairly to the measurements of the deviations of a Thompson short-coil reflecting galvanometer, in response to the current induced in a Bell telephone by the same consonant sounds. An attempt was made to show the effect of the pneumatic pressure upon the coincident vibration of the membrane as is shown in the second series of plates herewith presented, by obtaining first a measure of the excursion of the membrane in response to a consonant sound, the glass plate being at rest; second, a logographic curve made with the plate moving at the rate of five millimetres in the second, and finally a third, phonauto-logographic tracing made with the plate moving at the rate of five centimetres in the second, representing the excursion consequent upon the pneumatic pressure with the vibrations resulting from the combined vowel sound.

As the pneumatic pressure, and consequently the tension of

* W. H. Barlow, F.R.S., "The Logograph," reprinted in the Popular Science Review, London, July, 1874.

† Phenomena of Audition and the Telephone. C. J. Blake. British Society of Telegraph Engineers, London, May 8th, 1878.

the membrane, varies considerably during the production of the consonant sound, a corresponding influence upon the vibration of the membrane is exerted, as is shown in the original tracings when examined under the microscope.

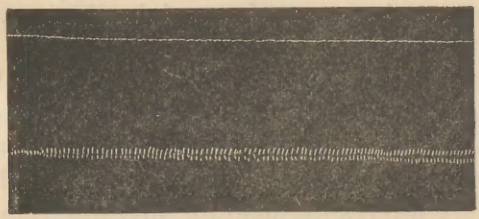

FIG. 1.

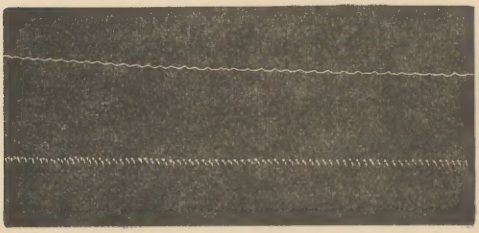

FIG. 2.

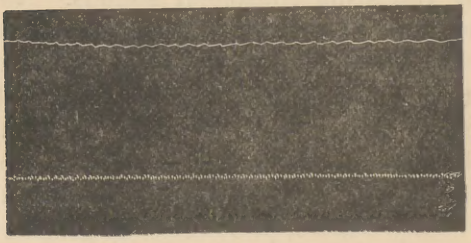

FIG. 3.

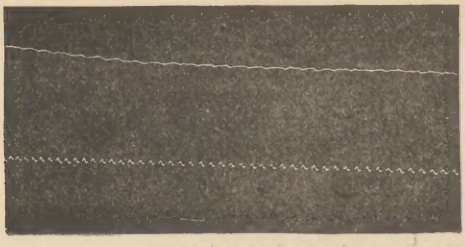

FIG. 4.

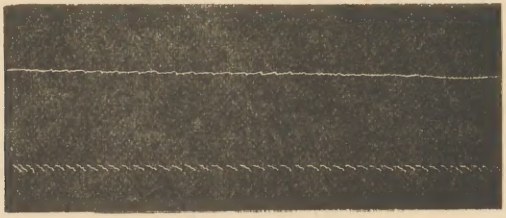

FIG. 5.

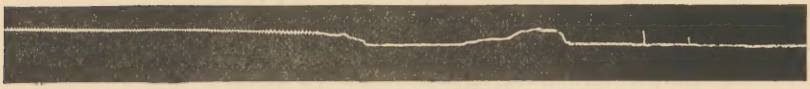

FIG. 6.

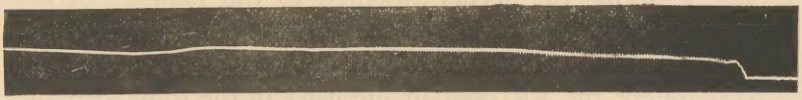

FIG. 7.

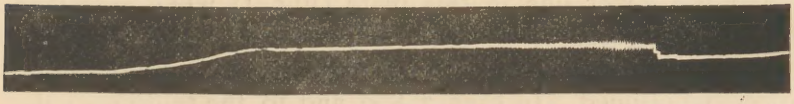

FIG. 8.

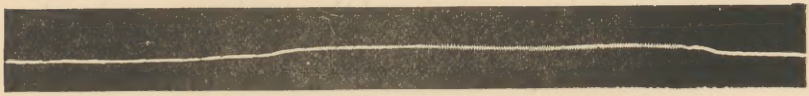

FIG. 9.

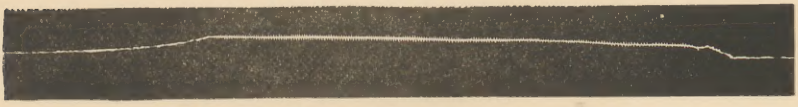

FIG. 10.

NOTE IN EXPLANATION OF THE DRAWINGS.

FIG. 1. Vowel sound A,* 896 v. s. and octave.
FIG. 2. Vowel sound E, 1,792 v. s. and octave.

* Pronounced according to the German language, not the English.

FIG. 3. Vowel sound I, 2,304 v. s. and octave.
FIG. 4. Vowel sound O, 448 v. s. and octave.
FIG. 5. Vowel sound U, 1,632 v. s. and octave.
FIG. 6 illustrates the measurement of the excursion of the membrana tympani under the pneumatic pressure occurring in the production of the consonant sound B, and also the logographic curve of B, with a portion of the phonauto-logographic curve of B.
FIG. 7 represents the phonauto-logographic curve of B.
FIG. 8, the phonauto-logographic curve of D.
FIG. 9, the phonauto-logographic curve of F.
FIG. 10, the phonauto-logographic curve of K.

In Figs. 1, 2, 3, 4, and 5, the upper line represents the sound curve, drawn by the stylus attached to the malleus, of the vowel sound at the pitch indicated, the lower line being the same vowel sound one octave higher, the tracings representing very fairly the increase in intensity of the tone with the rise in pitch. This is more marked with the vowel sound A, and the lower line in this plate (Fig. 1), when examined under the microscope, shows tracings between the dots represented which suggest the curves obtained by the photographic process mentioned. In Figs. 7, 8, 9, and 10, the tension of the membrane under the pneumatic pressure of the consonant sound so far limited the excursion of the membrane in vibration as to render it necessary to enlarge the tracing four diameters before reproduction by engraving.